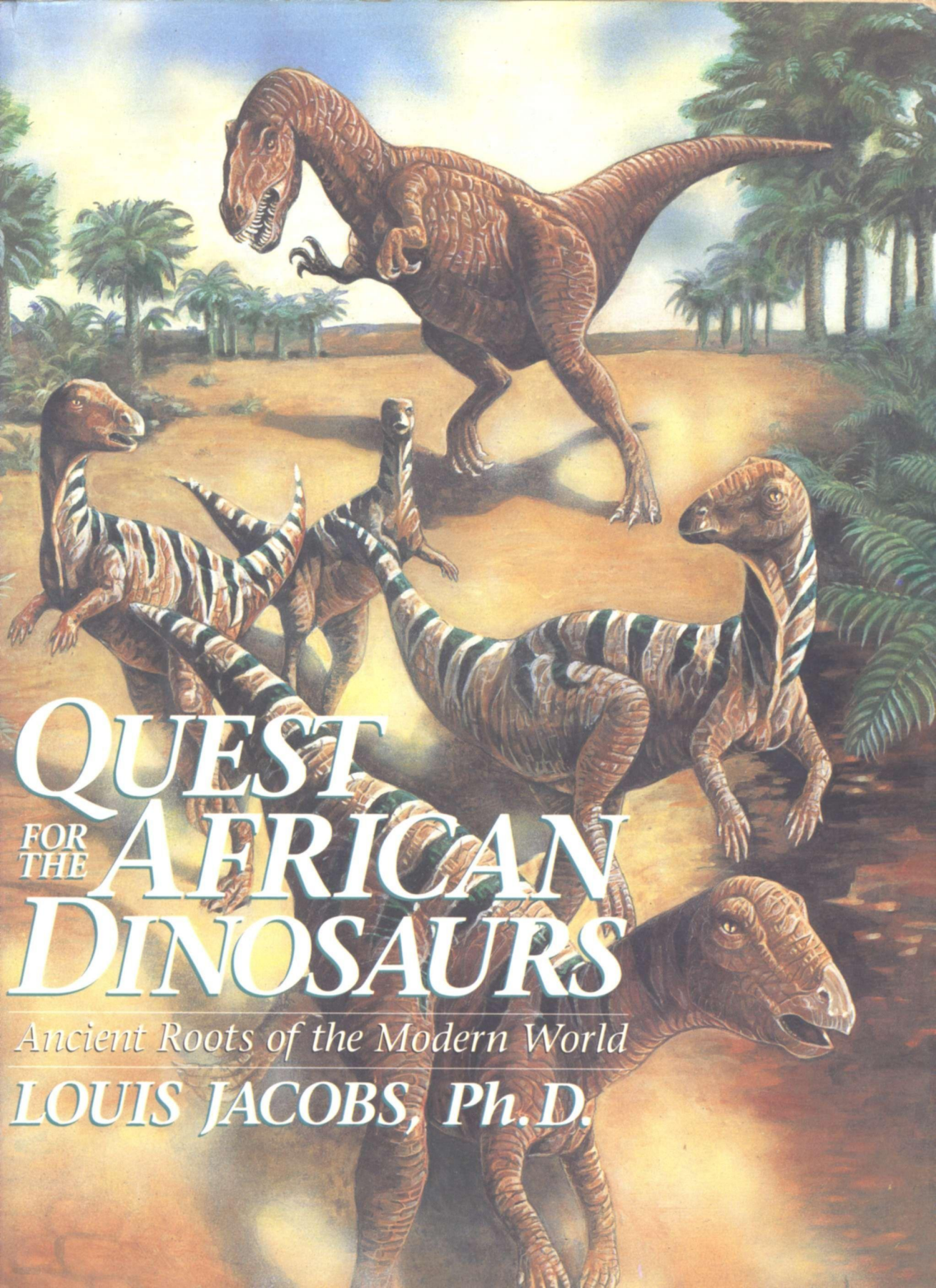

QUEST FOR THE AFRICAN DINOSAURS

Ancient Roots of the Modern World

LOUIS JACOBS, Ph.D.

9

A LIVINC DINOSAUR?

FOSSILS OF MANY KINDS representing the world of 100 million years ago can be found today, preserved in the ancient rocks of Africa. Many of them are strange. However, on one of my flights to Malawi I read in an airline magazine of something even more strange. It was a "serious scientific expedition" to Darkest Africa in search not of fossils, not even of living lions, hyaenas, or elephants, but of a *living* dinosaur. Not birds, but dinosaurs in the traditional sense. A sauropod. Something presumably resembling brontosaurus, or maybe a Malawi-saurus. The expedition I read about is not the first to propose the search. There have been at least four others. These are not scientific expeditions. They are science fiction—and not particularly good science fiction, either, judging from the 1985 motion picture *Baby: Secret of the Lost Legend,* which is based on such a search.

Africa, the Dark Continent, the land of the unknown, is a cliche, an allure even now. That mystique used to be justified. At least part of it goes back to the intense interest that the Victorian era took in the search for the headwaters of the Nile. In the latter half of the nineteenth century the geography of Africa really was much more poorly known than that of most other continents. Back then the Interior was a blank spot on the British map, even though in earlier centuries the Portuguese had a better reckoning of it. Now Africa is no longer

so remote, so hidden, as it used to be. The big questions of old, such as the courses of its rivers and the traces of its mountains, are not obscure.

The River Nile originates from the lake region of East Africa and debauches into the Mediterranean Sea. The River Congo, through the Lualaba and the Ituri, has its headwaters near those of the Nile. It flows north then west from the lake region to drain the fetid swamps of Central Africa into the Atlantic. Only one great lake, Lake Malawi, drains south, out through the Shire and then the Zambezi to the Indian Ocean. The rivers were highways when the continent opened up to Europeans. Explorers used them to travel through the land.

Daniel Defoe's fictional hero Captain Bob Singleton, the pirate, crossed the African continent through his author's pen, on paper and in the imagination, but much before his time. Defoe wrote Singleton's made up travel adventures more than a century before Livingstone actually did cross the continent in 1854. Livingstone followed a course along the Zambezi for most of the way. He made it to the Atlantic coast and then he made his way back. The truth of African exploration is stranger than fiction. Men like David Livingstone are not normal. He was caught up in the search for the headwaters of the Nile. Livingstone was a missionary, but he, like Richard Burton and John Speke, explored the Rift Valley where the great lakes of Africa hang like delicious wet grapes on a dry brown stalk. He searched for the headwaters of the Nile for years. He thought he had found them, but he had not. He was still searching when he died.

Henry Stanley searched for Livingstone and became infected with the fever of African exploration. *Bula Matari,* "the breaker of rocks," as Stanley became known to the natives, took on Livingstone's quest. He followed the course of the Lualaba, not to the Nile as he wanted but all the way to the Congo, even to the west coast of Africa.

It is all part of the tradition, this searching and exploration of Africa. The explorers, driven men, knew what they were looking for. They had their reasons, and the reasons were valid. The searches made sense to the nineteenth-century world. The Nile does have headwaters, and they were important to find. Livingstone was alive when Stanley searched, and he was important to find. The early explorers opened up the continent to Europe. There are no more blank spots on the map. The only way not to be aware of Africa nowadays is to ignore, for whatever reason, the common, hard-won knowledge of that continent.

Expeditions to Africa in search of living dinosaurs, like the one I read about in the airline magazine, are based on word-of-mouth reports of a legendary beast called *Mokele-Mbembe.* The phenomenon is no different from the reports of the Loch Ness Monster, Yeti, or Bigfoot. The only real difference is that in this case it is set in Africa. *Mokele-Mbembe's* haunts are alleged to be the Likouala Swamp of the People's Republic of the Congo, right in the extreme depths of the continent. This is the northern part of the huge swampy region traversed by Stanley on his seven-month float down the Congo River. *Mokele-Mbembe* is thought to look like a brontosaurus—the word used by English-speaking searchers—based most strongly, in their opinion, on the identification of mug shots by natives. A man named Appolonaire encountered by one of the expeditions even sketched a crude effigy in the soil that was said to resemble a sauropod. He had seen the beast, he said, at the village of Pikunda, not far from the route Stanley took on his third African expedition. On that one Stanley left instructions with his rear guard to join him with extra supplies and ammunition. The rear guard never caught up with Stanley, partly because they heard he was dead. Supposedly he had been murdered in retaliation for the atrocities he allegedly bestowed on the natives. Rumors were rampant among the local populations that human arms and legs had been seen in Stanley's cooking pots. There was graphic evidence of a quality equal to that used in the search for *Mokele-Mbembe.* Stanley, who was assuredly not dead, wrote, "Sketches by an amateur artist are said to have been made of whole parties indulging in cannibal repasts."

Stanley, of course, had not been murdered, the English were not cannibals (any more than the natives were), and the sketches of Stanley's cooking pots had no bearing on reality. I do not know what the Congolese Appolonaire drew, or why, but the report that he sketched a sauropod does not substantiate their existence alive in the Congo.

Nevertheless an expedition to the Likouala Swamp could be scientifically very important if questions of more general significance were being asked: What is the diversity of life—plant and animal—in the Likouala Swamp? How many species are there? What is the ecological structure of the community? How does it compare with other tropical jungles, such as the Amazon? What is the contribution of the African tropics to the global ecological balance? What are the economically important species? Which species have medicinal properties? How has the swamp changed through geologic time? How is it being affected by human impact? Is it being destroyed? Are steps necessary for

conservation? How can the people of the region best and most effectively utilize their resources?

If questions such as these were addressed, sauropods, if they existed, would turn up in due course. Whether they did or did not, we would have a much greater knowledge about this part of the world and it would be of much greater consequence.

But surely, one might insist, dinosaurs *could* be living somewhere in Africa, could they not? Sure, they could. And that would be fun. But how likely is it? The odds are so great against it that the probability of finding a living sauropod has, for all intents and purposes, reached zero. I regret that it is—sadly—a virtual certainty that none will be found alive. But it does make sense.

Not a single really new kind of large animal has been discovered in Africa since the okapi, a relative of the giraffe, was named in 1901, very nearly a century ago. And people have looked. The pygmy hippopotamus was discovered in 1912, but regular hippos were already familiar long before then. The giant forest hog was found in 1902, but people already knew that pigs were around. Almost certainly some less conspicuous small animals still remain to be discovered and described from many parts of the world. Things such as mice, insects, or fish are sure to have multitudes of unnamed species. Perhaps even some larger terrestrial species will be discovered. But while there may be species new to science, they are unlikely to be grosslv different from what is already known.

The circumstances surrounding the European discovery of the giant forest hog, *Hjlochoerus meinertzhageni,* are well documented, so they ought to be informative as to how new and large animals were discovered in the Victorian past. Richard Meinertzhagen, for whom the species was named, recorded the events in his diary. A soldier and an avid sportsman in the sense of early twentieth-century Africa, he spent much time afield. He lived in the bush, being stationed in several remote and mountainous posts in Kenya. He kept a scrupulous record of his daily life.

Meinertzhagen writes in his diary on 5 September 1902 while on a trip to the Aberdare Mountains,

> While wandering in the forest at dusk I saw two animals I have never seen before. Unfortunately I caught only a fleeting glimpse of them. . . . [One) was an enormous black pig, probably a forest variety of the warthog. Here again I only just saw the beast for a moment.

Then, in 1904, two years later, while on a punitive expedition against the Embu tribe of Mount Kenya:

> Just as we were emerging from the forest the leading man of my patrol fired a shot at something which I could not see, and on coming up I found he had killed a huge pig with long black hair, unlike anything I ever heard of. I put a piece of the skin into my haversack but left the carcass. I shall send to bring it in tomorrow. As we have several of the enemy in the vicinity I could not remain and examine her, for she was a sow, but I now wish I had brought home the skull, which was unlike that of any pig I know.

Then on 24 March 1904 he wrote,

> I may as well note down what I know of the huge forest pig which I found on 11 March in the Kenya forests. Up till now I have seen but one, a sow, and she after she had been killed. All I have of this beast is a small piece of skin. 1 asked all my Masai levies whether they knew the animal and they all said they did but that it lived in thick forest and was called *elguia* by them. They made their shields of its tough skin, and I actually purchased a shield which purports to be made from the forest pig. Its owner told me he bought the skin from a Dorobo hunter who had killed it on the Mau escarpment, which shows the animal has a wide range.
>
> Towards the end of the expedition my men found several large pieces of skin in villages. One piece in particular is enormous and could never have been taken off an animal much smaller than a donkey. The hair is long and black, measuring some 10 inches on the crest.
>
> On returning to Fort Hall I enquired from the Wakikuyu concerning the pig and found they all knew it well, calling it ***numiira.*** I have offered a cow to the first man who can get me a complete skin with the skull.
>
> I have sent all the skin I have, together with the above information, to Ray Lankester at the British Museum. I think there can be no doubt that the animal is new to science. It is exasperating not to have got a skull, but I live in hopes and shall hunt for him in forest when I get the chance.
>
> I am convinced that the pig I saw in the Aberdares . . . was this forest **Pig-**

The elements of Meinertzhagen's "discovery" of the giant forest hog (see Figure 41) are personal observation, tangible remains, and verifiable general

knowledge of the beast from local inhabitants. Science requires that there be something tangible, some repeatable, testable stream of logic, in order for an idea—or the claim of a new animal—to be accepted. African natives not only had names for the giant forest hog, they made shields from its hide. Meinertzhagen collected a piece of hide himself. In June 1904 Meinertzhagen even obtained a skull from one of the local inhabitants. That was particularly significant. Skulls are very important in mammalogy—the study of mammals—which is what the giant forest hog is, because almost every species can be distinguished by the structure of its skull bones and teeth.

Meinertzhagen wrote on 16 June,

FIGURE 4 1 : Giant forest hog. This species was unknown to the scientific community until early in the twentieth century. The circumstances surrounding its "discovery" were recorded and provide a model for how large "unknown" animals become known.

> But today I had even better luck. I had seen the tracks of pig in the forest and have often been out after them. It was only today when I was successful. I came on her in some thick stuff and killed her at about 40 yards. She is a young sow, and I was able to preserve the complete skull and skin, which I shall send to the British Museum. This is probably the first of her kind to be killed by a European.

So it was at the turn of the century. When Meinertzhagen moved to Nandi Fort in western Kenya in 1904, he found, "Forest hog are quite common here; I saw one today, and they frequently come into my vegetable garden at night." His infatuation with this animal continued. On 8 June 1905 he writes,

> I received by today's mail the description and figure of the skull of my new forest pig. Though the beast occurs in the forest all round my house up here, my efforts to obtain specimens have so far proved fruitless; yet the natives know the beast well. I have offered a handsome reward for a specimen in the flesh, but I suppose they cannot conceive that anyone can be so mad as to want a pig and merely regard my whim as a form of insanity.

The hogs visited his garden:

> I now have most English vegetables growing and they are now being raided by jackal, small antelope and forest pig. I sat up last night and saw a forest duiker and two forest pig, one an enormous boar, calmly rooting up my potatoes and tomatoes. . . . Some day I shall pepper those pig or put a bullet into one.

The discovery of the living okapi was not much different from the discovery of the giant forest hog. In 1900 the okapi was unknown to Western scientists, although now they can be seen in most zoos. The okapi is a short-necked giraffe that inhabits the deep jungles of the Congo Basin, where dinosaurs are suggested to be living now.

At the turn of the century pygmies told Sir Harry Johnston—the same Sir Harry who had earlier secured Nyasaland, now Malawi, as a British Protectorate—of a mulelike animal with zebralike stripes. He sent two pieces of the

striped hide that had been given him back to Britain, and in 1901, on the basis of that evidence, it was named *Equus? johnstoni* after him. Later that same year, with better and more specimens, the beast was correctly determined to be a member of the giraffe family. Therefore, the name was changed to *Okapia johnstoni* because it is certainly not a zebra or deserving of the horse name *Equus.*

While the okapi is a distinct species of giraffe, some investigators early in this century thought that it bore some resemblance to extinct giraffes, also with short necks, which had been known from fossils for some time. Cryptozoologists, as such people who investigate claims of hidden species like to call themselves, picked up the okapi as an extinct animal found alive millions of years after it was supposed to have gone extinct, as *Mokele-Mhemhe* is supposed to be. However, the okapi clearly is not one of the formerly known fossil species, notwithstanding the ancient record of the giraffe family or the primitive shortness of the okapi's neck.

The discoveries of the giant forest hog and the okapi are particularly enlightening when compared with the rumors of another animal, supposedly living in the same general area as the giant forest hog, but with no tangible proof of its existence. That one is called the Nandi bear. There are two theories as to what a Nandi bear may represent. One is that it is really a honey badger or ratel, a large member of the weasel family. The other is more appealing to long-lost-animal enthusiasts. It has been suggested that the Nandi bear is really an extinct mammal called a chalicothere. Chalicotheres have long, horsy heads, long front limbs, and claws on their fingers. They are gorilla-sized or larger. While chalicotheres have a long and seemingly good fossil record in many parts of the world including North America, Europe, Asia, and Africa, it is as hard to imagine their existence in western Kenya today as it is to imagine living sauropods in the Congo, monsters in Loch Ness, or Abominable Snowmen on the tops of mountains. If chalicotheres existed now, they would have been found out just like the giant forest hog was. If there is anything to the Nandi-bear story besides imagination, I suspect it may be the word-of-mouth description of gorillas passed across the continent from areas where they live to areas where they do not.

There are four genera of mammals—worldwide—known first as fossils, then discovered to have living representatives. One is a peccary, a pig relative from South America. One is a member of the dog family, also known from South America. One, not always put in this category, is a small, mouselike

opossum known from Australia, the first live one, interestingly enough, being caught in a ski hut in the Australian Alps. The last example is a fruit bat from New Guinea. None of the fossils is highly distinguished from other, previously known relatives, and none is anywhere near the tens or even hundreds of millions of years of dinosaur antiquity. If sauropods, so very different from anything else alive today, were still extant in Africa, surely some remains of them, even a scrap of skin as in the case of the okapi or forest hog, would be available to verify the claim.

The showpiece of cryptozoological discoveries is the living fish *Latimeria* (Figure 42), the coelacanth discussed briefly in Chapter 8. It belongs to a group of bony fish that was thought to have been extinct for eighty million years. Then in 1938 Miss M. Courtenay-Latimer was intrigued by a strange fish caught in the Indian Ocean off South Africa near the mouth of the Chalumna River. A living coelacanth had been caught! This was truly a stellar discovery. While *Latimeria* itself, as a distinct species, has no fossil record, it *is* a member of the larger coelacanth group that had been unknown for the vast length of time between the Age of Reptiles and now. To this day, living coelacanths are known only from a small patch of the ocean. The first was caught by a South African fishing trawler. All the rest have been caught near the Comoro Islands between Madagascar and the African coast. The Comoros were the home of the porters who deserted Livingstone and reported him dead, leading to Stanley's search for Livingstone. Living coelacanths are known from nowhere else but those tiny spots, but mostly the Comoros, in all the vast, vast ocean.

Certainly this is an example of the fossil record somehow playing tricks on us. It does not adequately reflect the evolutionary history of coelacanths. Even until today there have been no fossil discoveries to fill the eighty-million-year gap in the fossil record. The reason most likely lies with the environmental preferences of fossil and living coelacanths. Fossil coelacanths are preserved in shallow-water environments, both fresh and marine, that are abundantly represented in the rock record. *Latimeria* lives in deeper water, 650 feet deep, 200 meters or so, in a marine environment, and in a very specific habitat as well. The rugged sea bottom along the steeply sloping feet of the Comoro Islands is formed from lava. *Latimeria* hangs out in and around caves in the lava rock, foraging and swimming about, for the most part casually. Such environments as those frequented by *Latimeria* are rarely preserved in the rock record, especially in such a state that fossils might be preserved with them.

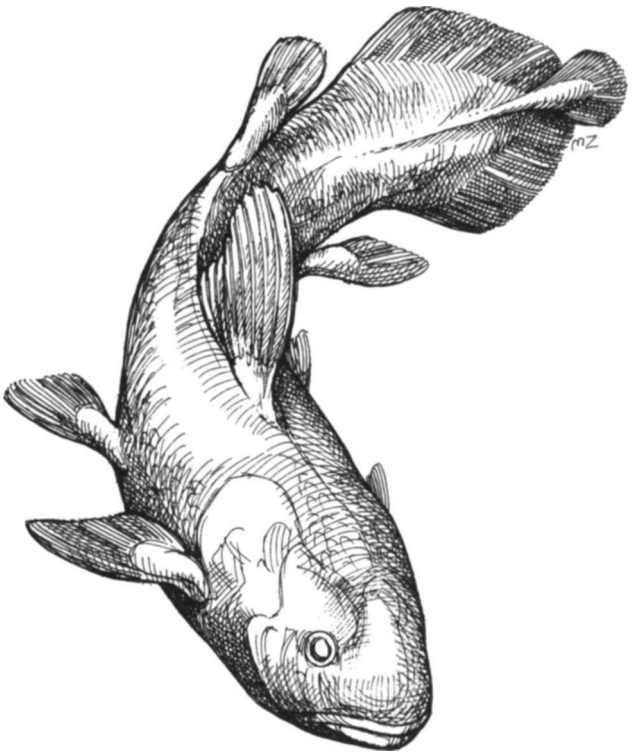

FIGURE 42: The coelacanth LATIMERIA CHALUMNAE. The ultimate living fossil, coelacanths were thought to have been extinct for eighty million years until one turned up alive off the coast of South Africa.

Moreover, they may not last all that long. The Comoros are volcanic islands, and as we have seen, oceanic volcanoes move away from their lava source by plate tectonics and become submerged to greater depths. *Latimeria's* habitat in the Comoros cannot be older than the islands themselves, which is only a few million years. That creates an interesting paradox: Here is a living fossil, disjunct from its predecessors by eighty million years, yet living along the undersea slopes of an island perhaps only five million years old. Clearly *Latimeria* must either live undiscovered elsewhere besides the Comoros (and perhaps near the Chalumna River) or it is strictly limited in its distribution. Either way it has been doing some underwater island hopping along the feet of newly created volcanoes. I suspect it is severely limited in its geography and that it has been hopping volcanoes for a long, long time.

Latimeria is anatomically and behaviorally an extremely interesting animal. It is heavily built, and like some other fish that live at similar depths, its flesh is quite oily. The tail fin has three lobes, an extra one compared with other fish. The paired fins, representing the arms and legs of terrestrial animals, are fleshy with bony internal supports extending from the body into the fins, thus disclosing the coelacanth's cryptic evolutionary relationship to lungfish and tetrapods. It does not utilize its paired fins to walk along the bottom, but often its slow, deliberate movements are synchronized and alternating. Its movements appear as a fishy foreshadow of the locomotion in terrestrial vertebrates. It is a carnivore, feeding on fishes and squids, perhaps other things as well. Even though it is carnivorous, it is generally sluggish, leisurely maintaining its position in the water with casual flicks of this fin or that. Perhaps most intriguing of its behavioral traits is its habit of standing on its head. There are organs in the snout that are quite sensitive to electricity. The application of a small amount of electrical current to the water near a *Latimeria* will elicit a head-standing response. It has the same behavior naturally, without a researcher applying the current. That suggests that *Latimeria* uses electricity to sense its environment, possibly in locating other animals.

With *Latimeria* living now as it does, and with the ancient fossil record of coelacanths, which is reasonably good except for that eighty-million-year gap, showing a diversity of species and habitats for *Latimeria's* cousins, the coelacanths must have a very complicated story to tell. Early on, coelacanths inhabited both salt and fresh water. The same kind of fossil coelacanth is known from the Cretaceous of West Africa and from Araripe in Brazil. (A pterosaur is eating a coelacanth in Figure 35). At eighty million years ago the more easily observed freshwater and shallow-marine species became extinct.

Descendant species such as *Latimeria* may never have been particularly abundant since the Cretaceous. They may have just bounced along from submerged island to submerged island, their range and abundance diminishing with the passage of geologic time. Because we know that *Latimeria* is different at the family level from other coelacanths, we know that evolution in the group did not stop, it just changed venue. *Latimeria* is a living fossil, to be sure, and the reason is because it still shows some primitive features, at least in its anatomy, that are little changed from older fossil species. In other regards *Latimeria* is undoubtedly derived with respect to the ancestral condition. It is a living fossil, but it is its own unique animal at the same time.

Even though the example of *Latimeria* is widely touted by the cryptozoology community, there is no meaningful analogy between the discovery

of a new family of fish over fifty years ago, which in one sense is what the discovery of *Latimeria* amounted to, and the predictive ability to find living dinosaurs, also believed to be extinct since the Age of Reptiles. The difference should be obvious: We have the fish; we do not have the dinosaur. No matter how remote the Likouala Swamp is, it is not as remote as the ocean around the Comoro Islands, 650 feet down. It is much more likely that a living sauropod would be found, if they in fact existed, than that *Latimeria* would be found, much less observed and photographed in its natural habitat.

There is another big difference between the discovery of *Latimeria* and the search for living dinosaurs. The search for living dinosaurs is justified only on the basis of individual testimonies. There is no objective evidence for their existence in the present whatsoever. This approach had absolutely no role in the discovery of *Latimeria.* Miss M. Courtenay-Latimer was not out chasing rumors, nor searching for monsters under her bed or in her extended backyard. She was a museum specialist making collections of fish on a South African trawler. An odd fish was caught, and then, through the attendveness of the captain, it was brought to her eye. She knew she would find fish on a fishing boat. Small wonder. The shock came when she recognized what the fish was. The scientific significance of her discovery cannot be challenged, but the existence of *Latimeria* came as no surprise to the natives of the Comoro Islands, who had caught them before. The scientific significance came from knowing what it meant. *Latimeria* is a living but distant relative of the fish ancestral to the first backboned animals to leave the water and take to the land permanently.

Even if sauropods were still alive, why should Darkest Africa be their home as opposed to, say, Long Island? The apparent reason is that Africa is unknown in the West, at least to those people mounting the expeditions to the Congo. Dinosaur survival in familiar, well-known, or populated corners of the United States would tax the credulity of even the most dyed-in-the-wool cryptozoologist, but it is acceptable, in some circles, to believe sauropods are in Africa. However, there is a more *ad hoc* reason that is usually offered.

The Congo Basin is considered by cryptozoologists—and, in fairness to them, by some scientists—to have been environmentally stable since the end of the Age of Reptiles sixty-six million years ago. The environment is not supposed to have changed in any significant way. At all. The end of the Age of Reptiles is the magic time because that is when dinosaurs vanished from the fossil record everywhere else in the world. If the swamps of Africa were

never-changing, dinosaurs could have survived in the sanctuary of this slimy, murky, unknown refugium.

However, there is abundant and convincing evidence that environmental conditions in Africa have changed with time, that sauropods were not limited to swamps, and that the fossil record with its vast array of species contains not one sauropod specimen from any place on Earth, not one scrap of sauropod bone, since the Age of Reptiles ended. All that must be combined with the observation that there is not one shred of tangible evidence, not a piece of skin, not a toenail, no evidence at all that sauropods live today—anywhere.

It is extremely unlikely that the parameters defining the environments of the African continent have remained constant, have not wavered, for sixty-six million years. The Earth, as a sphere, shows variations in temperature as one goes from the tropical regions adjoining the equator to the temperate zones, and into the cold high-latitude boreal and arctic climates. In addition to variation in the sun's heating capacity relative to the curvature of the Earth, oceans and landmasses have different thermal properties, heating up and cooling down at different rates. Heat differential and the spinning of the Earth create atmospheric and oceanic currents, which distribute thermal energy about the globe in patterns specific to the shapes of the currents.

It should be obvious that physical changes in the geography of continents and oceans will change climate. If continents drift apart through plate tectonics, the climate will be different from what it is at times when landmasses are conjoined. Continents that change latitude through time experience an evolution of climate. The existence of shallow seas covering large portions of continents will affect climate. The formation of new oceans where none existed previously will modify ocean currents and influence climate. But on top of all that there are astronomical cycles that impose climatic fluctuations on the Earth. The amount of energy from the sun reaching the Earth varies in a recurrent fashion. There are several causes. The Earth wobbles on its axis of rotation in a predictable way, completing a cycle in about 26,000 years. The tilt of the Earth's axis also varies over a period of about 41,000 years. Moreover the Earth's orbit around the sun is not perfectly round, and there is variation in the time of year that the Earth is closest to or farthest away from the sun. This third variable has a cycle of about 100,000 years. All three of the cycles are perpetually influencing the amount of energy received from the sun—and its distribution on the globe—and therefore they influence climate through time.

The conclusion is quite clear: The climate and environment of any given place on Earth will change. It will change because of the effects brought about by the physical rearrangements of plate tectonics, and it will be changed by the imposition of astronomical cycles. Associated with all of that, there are any number of small- or large-scale influences on climate, some purely physical, others caused by biological activity. All of these various influences contribute to the overall pattern of climate through time, to the environments and ecosystems within which organisms evolve, and to the contexts in which species go extinct.

If climatic change is true from a theoretical perspective, then we should be able to see evidence of it in the rocks, and in fact we can. Evidence of glaciers and ice ages have long been seen in rocks. Ancient buried soils leave telltale clues as to the climatic condition under which they formed. Some of the most compelling evidence for past climate comes from fossils. The adaptations of plants and animals often indicate the restrictions under which they must live. Fossil pollen is frequently particularly informative when it can be recovered, which is surprisingly often. However, recent developments in geochemistry have provided some of the best new evidence of ancient climates.

The Earth's atmosphere is made up of a mixture of gases, mostly nitrogen, but also oxygen contributed by photosynthetic plants, carbon dioxide, water vapor, and other minor components. Atoms making up these gases come in various "flavors" at the subatomic level, and the alternative "flavors" are called isotopes. Any rock forming in chemical equilibrium with the atmosphere, or an organism—such as a clam, for instance—building its shell from elements in equilibrium with the atmosphere will reflect the isotopic composition found at that particular time in the air surrounding the Earth. Even though we are talking about elements and isotopes and atoms and molecules, sophisticated techniques allow the weights of different isotopes to be measured with great precision.

Oxygen atoms of concern here come in two isotopes. One isotope is heavier than the other. When dealing with such small particles as atoms and molecules, you would think that such a tremendously minute difference could not possibly have any consequence. But it does. Oxygen combines with hydrogen to form water molecules. Those with an atom of heavy oxygen will weigh more than a water molecule made with a light oxygen. Subtle differences in isotopic composition affect the physical properties of the water.

These slight differences influence the way the water molecules behave, particularly, how easily they go into the gaseous state by evaporation and, once there, how they condense and fall to the Earth as rain or snow.

The system is complicated, but the end result is that some variations in climatic parameters, such as temperature, have a correlation with oxygen-isotope composition, and that relationship can be measured. Since rocks or shells forming in equilibrium with the atmosphere will reflect the ratio of light-to-heavy oxygen at the time of their formation, a stratigraphic section, usually of marine rocks and fossils, will record the history of climate-related oxygen-isotope variations through time. That is how a long geochemical record of the Earth's climate is built up. Once the technology is at hand to make the measurements, and after good samples have been collected, it is basically quite simple to understand.

Isotopes of oxygen are useful paleoclimatic tools, but the temperature regime determined from them is usually an average for the Earth as a whole. That is enough to tell us that there have been episodes of significant global climate change. The evidence is clear on that. If the climate of the whole Earth has undergone changes, no place has been unaffected. Still, the climatic history of specific regions of the globe—the Likouala Swamp for instance—in contrast to the Earth's average climatic values measured through time, is often more difficult to decipher. A variety of methods is often used depending on what is available, including pollen samples extracted from sediments, environmentally sensitive ancient soils, fossil animals and plants, even the shape of the land—geomorphology, as it is called.

In order for swamps to exist, two basic requirements must be met: There must be adequate rainfall in the watersheds that empty into them, plus there must be a slow drain through which the accumulated water exits. That is what keeps swampy basins full. Water must pond and meander, stand and stagnate, rather than flow swiftly and cleanly out of the system. Modify either the amount of water or the efficiency of drainage and the conditions producing the swamp will be altered. The swamp will change. It will transform to reflect changing climate and rainfall patterns, and to reflect the development of mountains and other landforms that modify the drainage basins. Major Earth processes such as plate tectonics and continental drift create mountains and oceans, and as we know, they affect climate.

At 100 million years ago South America was just beginning to drift westward away from Africa. Since then the two have continued to drift apart.

A continuously widening Atlantic Ocean must affect oceanic and atmospheric circulation—and climate. After 100 million years ago, and well into the Age of Mammals, much of North and West Africa was inundated by fluctuating seas, some extending quite close to the Likouala region of the Congo. These seas had an effect on climate that would have been expressed in Central Africa.

The mightiest mountains of the African continent reflect geological history that occurred after the Age of Reptiles. Kilimanjaro, the highest peak in Africa; Kerinyaga or Mount Kenya, with the second-highest peak; and the Ruwenzories or Ptolemy's "Mountains of the Moon," on the eastern edge of the Congo Basin—these are all young constructions associated with the development of the East African Rift System. The Congo Basin drains the western side of the East African highlands. In West Africa, Mount Cameroon and the Adamoua Plateau, just to the northwest of Likouala, are much younger than the youngest-known dinosaurs. The geological construction of all these highlands must have affected not only climate but also drainage patterns. Those drainage patterns that make the Central African swamps were not there throughout much of the Age of Mammals. Sure, there were drainages, and some spots were lower and wetter than others, but based on geomorphology the landforms that make the swamps today simply did not exist until geologically more recent time.

The geological context of Africa clearly reflects the dynamics of the past and argues against an everlasting and abyssal Central African swamp. On top of all this add the fluctuations of global climate recorded in oxygen isotopes and the cyclic fluctuations known to have occurred due to astronomical influences on the Earth. Given these circumstances, there is virtually no geological reason to think that the Likouala Swamp would have remained unchanged since the days of the dinosaurs.

Moreover, environmental evidence from a number of sources indicates that no extensive lowland rain forests such as characterize the Congo Basin today existed in Africa at 100 million years ago. Clay minerals of that age, weathered from African rocks and blown out to settle gently on the ocean floor, are of the kind characteristically formed in seasonally arid environments, not in swamps. Ancient soils and fossils of plants with special adaptations for dry or salty habitats demonstrate seasonal aridity.

There is, unfortunately, no fossil record from the depths of the Likouala Swamp. The reason is straightforward enough. It being a swamp, sediments

are being deposited, hidden under water and rank vegetation, rather than being exposed through erosion to disclose whatever fossils they might contain. Bones found in Niger, Cameroon, and Malawi show that African dinosaurs, including sauropods, inhabited a seasonally dry, hot land. The dinosaur fossils from Cameroon are located a short five hundred miles to the northwest of the Likouala. The geological changes that have resulted in uplift, erosion, and the discovery of fossils in Cameroon are related to the geological events that molded the northwestern margin of the Central African swamplands.

THERE IS ANOTHER related bit of science fiction—or rather pseudo-science—that is as equally untenable as living sauropods in Africa. It is the search for human fossils associated with dinosaur fossils. Glen Rose, Texas, a two-hour drive southwest of Dallas, is the world's headquarters for that search.

In this part of Texas the Paluxy River flows through 111-million-year-old rocks, roughly equivalent in age to those of Malawi, Cameroon, and Araripe in Brazil. The rocks at Glen Rose represent the remnants of old shorelines and mud flats from a time when the oceans covered much of what is now Texas. Dinosaur footprints—four-footed sauropods, strong-clawed three-toed theropods, and blunt "bird-foot" ornithopods—crisscross the ancient flats, preserving single moments of movement in the lives of these great beasts.

The existence of dinosaur trackways in the Paluxy River bottoms has been known since early in this century. The *Apatosaurus* at the American Museum of Natural History in New York, until recently, towered over Glen Rose footprints. Of course the bones of the *Apatosaurus* skeleton are about 145 million years old, and the footprints are considerably younger, a scant 111 million. The footprints bear the name *Brontopodus birdi,* named for Roland T. Bird who, with the help of WPA work crews, braved the floods of the Paluxy to collect fossils for the museum in New York. Footprints, as a special kind of trace fossil, not a part of an animal, but very certain evidence of its presence, and even its behavior, can be given their own scientific names.

During the Depression and after, a few of the local residents attempted to sell prints to bring in some scarce cash. Digging up dinosaur footprints is tough work. Apparently some ingenious entrepreneurs decided it would be easier to carve new footprints in stone rather than dig up old ones. The prints they chose to carve were in the shape of human feet.

Fundamentalists carried this a step further. (Excuse the pun; I could not resist it.) They identified some elongate erosional depressions—too large, but never mind—as human prints, making the claim that dinosaurs and humans walked together along the shore of the ancient Glen Rose sea. The claims are so outrageously false that the whole story would be comical were it not for the implications to public education of the fundamentalist agenda. Yet this nonsense is amazingly resilient. There is a museum outside of Glen Rose, the Creation Evidences Museum, that presents such absurdities as the petrified finger of a woman (really a burrow filling or concretion from the Glen Rose Limestone), abnormally large clothing to demonstrate that giants live, and a hyperbaric chamber. This last one is amusing. The logic goes something like this: In the days of Noah, with all that rain, the atmospheric pressure must have been much higher than it is now. Organisms, so the creationists say, grow to unnaturally large size under such atmospheric pressure. The hyperbaric chamber is a metal septic tank or some such container, presumably being converted to house kitty cats and other victims under pressure, allegedly to turn them into giants.

Believers in the association of dinosaur and human footprints reject virtually all intelligent explanation. And professional paleontologists, understandably, do not generally address the issue. If their time was spent continually dousing such frivolous backfires, legitimate research questions would go unaddressed. There is a tremendous body of knowledge testifying as to why the creationists are wrong on this issue. Libraries are full of it. Most all of what has been discussed in this book disproves it (and the rest is not relevant to the issue). Most creationists just simply choose to remain overzealous, unaware, uninformed, or purposely deceitful. There is no excuse for such shabby, innumerate logic when the problems the world faces require deliberate, considered, and reasoned solutions. Much to their credit, the latest falsifications of fundamentalist footprint dogma have been made not by professional paleontologists but by interested and curious, deeply wondering amateur paleontologists. Their attitudes are professional. Unfortunately whenever one allegation is disproved, another one, equally ludicrous, crops up.

There is a very simple reason why creationists cling to the Glen Rose footprints and insist on the co-occurrence of men and dinosaurs: Such an association would dispel the necessity of an Earth with vast antiquity. The entire history of creation, including the day of rest, could be accommodated

in the seven biblical days of the Genesis myth. Evolution would be vanquished. For creationists, living dinosaurs would do the same thing. The fundamentalist creationist movement was involved in at least one of the Likouala Swamp expeditions.

In Africa I ran into a fundamentalist footprint phenomenon similar to what I was familiar with in Texas. In 1988 the Cameroon expedition discovered over two hundred dinosaur tracks along the Mayo Rey, a stream in the Koum Basin not all that far from where we found Mesozoic mammals. This is a strongly Muslim area of the country near the border with Chad. We were very excited with the discovery of lots and lots of tracks. Back at Rhinoceros Camp, where we were staying, I told our local laborers about our "discovery.

They had the perfect reply: "Why didn't you tell us that is what you wanted to find? We could have taken you there to begin with."

It was explained to us that the footprint locality was well known to the native populace. Of course they did not know about dinosaurs per se. Nevertheless, from their way of life, living in the bush as they do, they could certainly recognize spoor, not that that is hard to do with dinosaur footprints, even if they did not know what creatures had made the trails. Some of the more devout and imaginative of them claimed that they had seen, in amongst the tracks, the knee, elbow, and forehead prints of one of the genuflecting Islamic faithful praying to Mecca. In the depths of Africa religious fundamentalism was showing itself among dinosaur tracks, just as it does back home in Texas. My friends were unable to relocate the human prints, so they could not be shown to me. But my guides were sure they had seen them before.

Now, Muhammad was not born until the sixth century. I do not know when Muslim influence first began to be felt in northern Cameroon, but it could have been fairly late, maybe within the last couple of hundred years—maybe even later than that. How might creationists interpret this? Could they argue that dinosaurs are not an Old Testament legacy, drowned in the Noachan flood, that they lived well into later times—when we have, incidentally, abundant and elaborate written records—and also well into the time that the Earth's big animals were becoming generally familiar? It would mean nothing if such arguments were made—just so long as they stay outside the science classroom.

THE REAL IMPORTANCE of that site in Cameroon is in the footprints. Dinosaur tracks, as fossils, are interesting. Unlike body fossils such as bones or teeth, trackways preserve an instant in time. It is fossilized movement, and therefore it embodies the spirit of the behavior that movement entails. Dinosaur tracks are not so rare as you might think. Their preservation depends on dinosaurs moving across the right kind of ground, soft enough to leave an impression, yet firm enough and not so mushy as to fill in the shape or obscure definition. Some of the trackways in Cameroon show the track-maker progressing from firmer to sloppier substrate. The size and weight of dinosaurs can be estimated using mathematical equations based on footprint measurements. Estimates of speed and gait can be determined. Directions of travel can be seen, and the sizes or relative ages of individuals likely to be traveling in the same group can be contemplated.

At the main track site in Cameroon, called KB-17 because it was the seventeenth locality found in the Koum Basin, there are four superimposed stratigraphic levels, four bedding surfaces on the tops of four sequential sedimentary strata, that hold most of the trackways. The site itself is a stretch of the Mayo Rey in the middle of the basin. The south bank is formed of Cretaceous sandstone and siltstone, tilted down to the north at a ten-degree angle. The river in flood during the rainy season sweeps the sandstone clean and exposes the surfaces pocked with tracks. Tracks are not the only sedimentary structures present. There are traces of ancient plant roots in at least one spot. There are ripple marks in places, showing that water covered the mud. There are mud cracks, showing it dried out. There is even a dinosaur track made on a flat surface, without ripple marks, but inside the track are mud cracks. Water collected in the imprint of the dinosaur foot, making a little pool. As the water evaporated and soaked into the ground, the mud inside the print was left to dry. As it did, the mud shrank and cracked. All that told in one print.

We spent several days on the slab measuring toes, angles, paces, strides, everything necessary to reconstruct the site on paper in a detailed map. My graduate student, John Congleton, did a fine job on the study, as you can judge from the summary that follows. At KB-17 we measured forty-seven separate trackways with a total of nearly 250 individual prints. The identity of the tracks matched what we expected from the scrappy bones and teeth we had found in our quarries at the east end of the basin, so together the two sets of data complemented each other in what they could say about the

dinosaurs that lived there. Both are important because no dinosaurs had ever been found in the Koum Basin before our expeditions went there.

Using body fossils, we could identify a couple of kinds of theropods based on meat-eating teeth. We also had a few sauropod teeth and one lousy tooth that could possibly have come out of a stegosaur's mouth. The sail-backed plant-eater *Ouranosaurus* (see Figure 3 in Chapter 1) was clearly present. The other members of the fauna, based on body parts, include crustaceans, lungfish and at least one other fish species, frogs, turtles, and crocodiles, most notably little *Araripesuchus*. And of course we got what we went there for—early mammals.

The footprints in the Koum Basin were all made by dinosaurs. Most abundant by far are theropod prints (like those of *Spinosaurus* in Figure 2). These show three narrow toes. More than one species is probably represented. Larger prints with three broad toes were made by *Ouranosaurus* in all probability. The smallest prints found are only about three inches or so in length. They also have three toes. They may represent a small species of dinosaur, or they could belong to young of one of the larger species. All three of the trackways made by the smallest feet were traveling to the northeast. We found no sauropod prints at KB-17, but just a short distance away there were unmistakable traces of sauropods walking in sticky mud. Their feet, adapted to bearing weight on the ends of pillarlike legs, sank deep into the ooze, leaving behind their traces, more holes than prints, as the feet were tugged from the mud that sucked to hold them in.

About half of the dinosaur trackways at KB-17 proceeded preferentially in a northeast-southwest direction. The other half were going the opposite direction. Perhaps the same individuals were going someplace in one direction and coming back from it in the other. Only one trackway is oriented east-west. Because the trackways are spread over more than four hundred yards' distance, they are on four different sedimentary bedding surfaces, and they represent several species of dinosaurs, the uniformity in the alignment of the trackways, whether coming or going, is striking. It suggests that some environmental obstruction, such as a river, controlled the avenue of movement. Perhaps the dinosaurs were moving parallel to a river channel, along its bank, or maybe they were constrained in the directions they could travel by some other physical barrier.

Most of the dinosaurs at KB-17 were walking when they left their prints; however, there are examples of other gaits as well. There are examples of

trotting and sprinting, as determined from the length of stride, and even some cases of speeding up and slowing down. Smaller dinosaurs seem to have been more active and agile than larger ones. One trackmaker may have been injured, as its trackway indicates it was limping along its way. At first I thought we had the marks of a tail dragging in one of the trackways, but I was wrong. When we mapped it out, the trackway showed a theropod making a turn, its outside foot making a broad sweep on the substrate. The lack of tail drags everywhere is significant and tells us something about how dinosaurs held their tails: up off the ground.

The trackways I remember most pleasantly at KB-17 can be interpreted in a controversial manner, and I really have no way of supporting my contention, but here it goes. There are two trackways at the western end of the site, both three-toed theropods but one considerably larger than the other. The larger is strolling along, but curiously it is walking in a curving path. The smaller of the two is walking along beside it, in the same direction, paralleling the curve to a remarkable degree. Could this be an adult and its offspring traveling along together? If so, it reflects a sophisticated social structure. Why not? I imagine a mother with young. It would not be startling really, it is just that I cannot prove that the two were actually walking together at the same time purposely rather than their associated tracks being a spurious and fortuitous coincidence. Parental behavior in herbivorous dinosaurs has already been documented in nesting areas and with juvenile aggregates. They also formed herds and flocks, some of them anyway. Theropods may well have behaved in the same general way, caring for young and perhaps forming packs.

There are no living dinosaurs in Africa, at least in the sense of relict sauropods, but we have certainly been able to learn a great deal about the ones found there as fossils. We can appreciate them as living animals, as well we should, because we know that in a more appropriate sense dinosaurs *are* still living. As we have already seen, they are living in the form of birds, the descendants of theropods. Birds are dinosaurs that fly, that have colorful plumage, and delicate eggs, and parents that care for the young. They are not sauropods, tyrannosaurs, or any of the other popular Mesozoic denizens, but we can better imagine those beasts by having an appreciation for the living dinosaurs. Through birds we can watch the mating dances of cranes and speculate on the courtship behavior of *Ornithomimus*. Birds, as dinosaurs, provide a fascinating new dimension to dinosaur biology—and a window through which to view it.

Ever since their origin from theropods, birds have undergone a marvelous radiation beautifully exemplified in tropical Africa. Is it not more grand, more inspiring, to see birds as living dinosaurs evolving through time with the ecology of a changing Earth, to learn about the past as it was and for what it means to the future, than to hold fast with no good reason to the notion that sauropods still live or that humans walked with giant dinosaurs? The Age of Reptiles is simply an expired world that no longer exists except through its legacy—its foundation for our modern world.